**RHODE ISLAND**
**DEPARTMENT OF ENVIRONMENTAL MANAGEMENT**
**OFFICE OF WATER RESOURCES**
**Groundwater and Wetlands Protection Program**

# Hydrologic & Hydraulic Modeling Guidance

The following packet has been designed to help engineers produce the best possible applications for the RIDEM Wetlands Program. It is not meant to be inclusive of everything required for an application submission, but simply to discuss several important pieces.

In particular, these guidance sheets are intended to provide Design Engineers with a brief conceptual overview of how to perform a hydrological analysis as well as a sample of the TR55 method.

In addition, these guidance sheets provide some direction on hydraulic modeling techniques.

Please Note: This guidance packet is for general information purposes only and is not meant to be used as a substitute for the Freshwater Wetlands Act or the *Rules and Regulation Governing the Administration and Enforcement of the Freshwater Wetlands Act*.

Office of Water Resources
1/17/02

# Hydrologic Analysis Information

(1) The analysis needs to compare the pre-vs.-post-project 2,10,25,and 100-year 24-hour Type III storm event peak runoff discharge rates (PRODR's). As per Regulation 11.02(20), if the project will result in an increase in the PRODR for any of the storm events analyzed, the analysis needs to evaluate the increase in terms of its effect on receiving water/wetlands peak flood elevations. The analysis needs to address how the increase (if any) could impair the wetland's ability to protect life and or property from flooding and/or flood flows.

(2) In order to obtain peak runoff discharge rate values which are derived from a Type III rainfall distribution, the runoff analysis needs to be performed consistent with the methods such as the Graphical Peak Discharge Method and/or the Tabular Hydrograph Method of TR-55 (Urban Hydrology for Small Watersheds, USDA-SCS, June 1986).

(3) The analysis needs to address the impacts to each distinct receiving wetland area separately. It is not sufficient to compare pre-vs.-post peak runoff discharge rates for the site or property as a whole. This is because even if there is no increase in PRODR on a gross site basis, there may be increases to individual wetland areas, depending on any changes in the distribution of the post-development runoff.

(4) The analysis needs to utilize the appropriate 24-hour rainfall amounts for the 2,10,25, and 100 - year storm events. Please use the following amounts:

| | **2-year** | **10-year** | **25-year** | **100-year** |
|---|---|---|---|---|
| Northern | 3.3” | 4.8” | 5.6” | 7.0” |
| Eastern | 3.4 | 4.9” | 5.7” | 7.1” |
| Southern | 3.4” | 5.0” | 5.8” | 7.2” |

(5) For any storm drainage system that is proposed, indicate the design storm. Indicate the design capacity of the drainage inlets, as well as the capacity of the conveyance system (pipes, etc.).

(6) If the drainage collection and conveyance system is not sized for the largest design event of the proposed peak runoff discharge rate mitigation measure (detention facility, etc), then the analysis needs to address how, and whether or not the intended discharge will actually reach the facility for which it was designed, or whether the excess runoff discharge will bypass the detention facility and discharge unabated to the wetland. If a portion of the runoff discharges without peak flow mitigation, the hydrologic analysis needs to specifically address the impacts of the effects of this on the wetland.

(7) Please number the pages of the submitted analysis.

# Rainfall Frequency Values for Rhode Island
## With 24-Hour Storm Duration

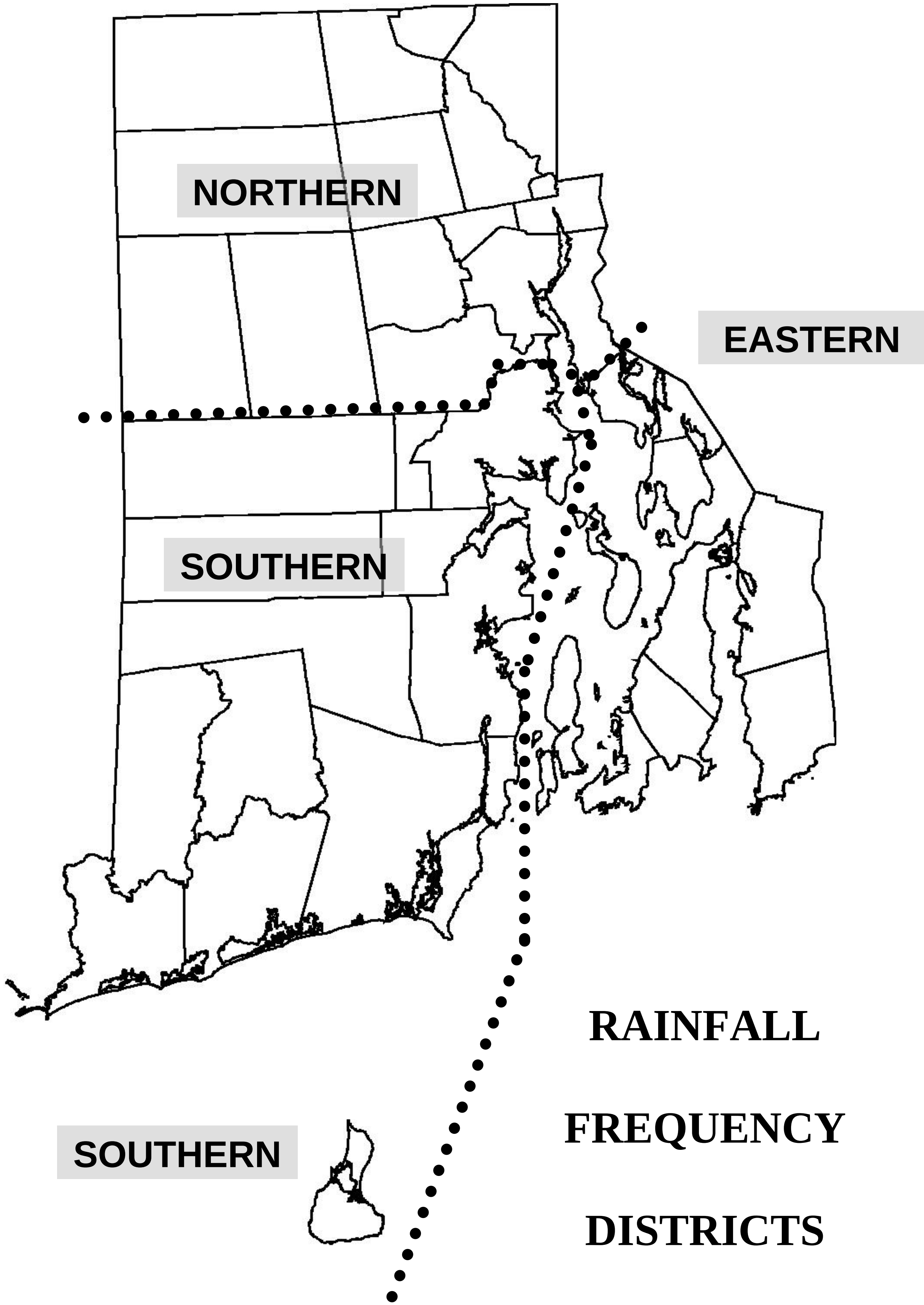
## Inches of Rainfall

| FREQUENCY | 1-Yr | 2-Yr | 5-Yr | 10-Yr. | 25-Yr. | 50-Yr. | 100-Yr. |
|---|---|---|---|---|---|---|---|
| **Rhode Island** | | | | | | | |
| Northern | 2.7 | 3.3 | 4.2 | 4.8 | 5.6 | 6.2 | 7.0 |
| Eastern | 2.7 | 3.4 | 4.3 | 4.9 | 5.7 | 6.3 | 7.1 |
| Southern | 2.7 | 3.4 | 4.4 | 5.0 | 5.8 | 6.4 | 7.2 |

Reference: U.S. Department of Commerce and Weather Bureau
T.P. 40, May 1961

Exhibit 2-3.1 CT-RI

April 1982




# RAINFALL FREQUENCY DISTRICTS

# Excerpts from the TR 55 Manual

## Worksheet 2: Runoff Curve Number and Runoff

Project: Heavenly Acres    By: WJR    Date: 10/1/85

Location: Dyer County, Tennessee    Checked: NW    Date: 10/3/85

Circle one:    Present    Developed

1. Runoff Curve Number (CN)

| Soil name and hydrologic group (appendix A) | Cover Description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio) | CN [1/] | | | Area ☒ Acres ☐ Mi2 ☐ % | Product of CN x Area |
|---|---|---|---|---|---|---|
| | | Table 2-2 | Fig. 2-3 | Fig. 2-4 | | |
| Memphis, B | 35% Impervious ½ acre lots, good condition | | 14 | | 75 | 5550 |
| Loring, C | 35% Impervious ½ acre lots, good condition | | 82 | | 1000 | 8200 |
| Loring, C | Open space, good condition | 74 | | | 75 | 5550 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | Totals = | 250 | 19,300 |

1/ Use only on CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{Total area}} = \frac{19{,}300}{250} = \underline{77.2}$;    Use CN = $\boxed{77}$

2. Runoff

| | Storm #1 | Storm #2 | Storm #3 |
|---|---|---|---|
| Frequency . . . . . . . . . . . . . yr | 25 | | |
| Rainfall, P (24-hour) . . . . in | 6.0 | | |
| Runoff, Q . . . . . . . . . . . . in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4) | 3.48 | | |

Figure 2-7 – Worksheet 2 for example 2-3

## Table 2-2a – Runoff Curve Number for Urban Areas[1]

| Cover Description | | Curve Numbers for Hydrologic Soil Group – | | | |
|---|---|---|---|---|---|
| **Cover Type and Hydrologic Condition** | **Average Percent Impervious Area[2]** | **A** | **B** | **C** | **D** |
| ***Fully developed urban areas (vegetation established)*** | | | | | |
| **Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:** | | | | | |
| Poor condition (grass cover < 50%) | | 68 | 79 | 86 | 89 |
| Fair condition (grass cover 50% to 75%) | | 49 | 69 | 79 | 84 |
| Good condition (grass cover > 75%) | | 39 | 61 | 74 | 80 |
| **Impervious areas:** | | | | | |
| Paced parking lots, roofs, driveways, etc. (excluding right-of-way) | | 98 | 98 | 98 | 98 |
| **Streets and roads:** | | | | | |
| Paved; cubs and storm sewers (excluding right-of-way) | | 98 | 98 | 98 | 98 |
| Paved; open ditched (including right-of-way) | | 83 | 89 | 92 | 93 |
| Gravel (including right-of-way) | | 76 | 85 | 89 | 91 |
| Dirt (including right-of-way) | | 72 | 82 | 87 | 89 |
| **Western desert urban areas:** | | | | | |
| Natural desert landscaping (pervious areas only)[4] | | 63 | 77 | 85 | 88 |
| Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders) | | 96 | 96 | 96 | 96 |
| **Urban districts:** | | | | | |
| Commercial and business | 85 | 89 | 92 | 94 | 95 |
| Industrial | 72 | 81 | 88 | 91 | 93 |
| **Residential districts by average lot size:** | | | | | |
| 1/8 acre of less (town houses) | 65 | 77 | 85 | 90 | 92 |
| 1/4 acre | 38 | 61 | 75 | 83 | 87 |
| 1/3 acre | 30 | 57 | 72 | 81 | 86 |
| 1/2 acre | 25 | 54 | 70 | 80 | 85 |
| 1 acre | 20 | 51 | 68 | 79 | 84 |
| 2 acres | 12 | 46 | 65 | 77 | 82 |
| ***Developing Urban Areas*** | | | | | |
| Newly graded areas (impervious areas only, no vegetation)[5] | | 77 | 86 | 91 | 94 |
| Idle lands (CN's are determined using cover types similar to those in table 2-2c). | | | | | |

[1]Average runoff condition, and I = 0.2S.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98 and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of condition may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

# Worksheet 3: Time of Concentration ($T_c$) or Travel Time ($T_t$)

Project: Heavenly Acres By: DE Date: 10/6/85

Location: Dyer County, Tennessee Checked: NW Date: 10/8/85

Circle one: Present Developed

Circle one: $T_c$ $T_t$ through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Sheet flow** ( Applicable to $T_c$ only) | | Segment ID | AB | | | | |
| 1. Surface description (table 3-1_ | | | DENSE GRASS | | | | |
| 2. Manning roughness coeff., n (table 3-1) | | | 1.24 | | | | |
| 3. Flow length, L (total L≤ 300 ft. | | ft | 100 | | | | |
| 4. Two-yr 24-hr rainfall, $P_2$ | | in | 3.6 | | | | |
| 5. Land slope, s | | ft/ft | 1.01 | | | | |
| 6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{\ 0.5}\ s^{0.4}}$ | Compute $T_t$ | hr | 0.30 | + | | = | 0.30 |
| **Shallow concentrated flow** | | Segment ID | BC | | | | |
| 7. Surface description (paved or unpaved | | | Unpaved | | | | |
| 8. Flow length, L | | ft | 1400 | | | | |
| 9. Watercourse slope, s | | ft/ft | 0.01 | | | | |
| 10. Average velocity, V (figure 3-1) | | ft/s | 1.6 | | | | |
| 11. $T_t = \frac{L}{3600V}$ | Compute $T_t$ | hr | 0.24 | + | | = | 0.24 |
| **Channel flow** | | Segment ID | CD | | | | |
| 12. Cross sectional flow area, a | | $ft^2$ | 27 | | | | |
| 13. Wetted perimeter, $P_w$ | | ft | 28.2 | | | | |
| 14. Hydraulic radius, $r = \frac{a}{P_w}$ | Compute r | ft | 0.957 | | | | |
| 15. Channel slope, s | | ft/ft | 0.005 | | | | |
| 16. Manning's roughness coeff., n | | | 0.05 | | | | |
| 17. $v = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ | Compute V | ft/s | 2.05 | | | | |
| 18. Flow length, L | | ft | 7300 | | | | |
| 19. $T_t = \frac{L}{3600\ V}$ | Compute $T_t$ | hr | 0.99 | + | | = | 0.99 |
| 20. Watershed or subarea $T_c$ or $T_t$ (add $T_t$ in steps 6, 11, and 19) | | | | | hr | | 1.53 |

Figure 3-2 – Worksheet 3 for example 3-1

**Sheet flow**

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute Tt:

$$Tt = \frac{0.007\,(nL)^{0.8}}{(P2)^{0.5}\,S^{0.4}} \qquad \text{[Eq. 3-3]}$$

where

Tt = travel time (hr).
n = Manning's roughness coefficient (table 3-1).
L = flow length (ft).
P2 = 2-year, 24-hour rainfall (in), and
S = slope of hydraulic grade line (land slope. ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix b.

**Shallow concentrated flow**

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft. use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may bot always be sdirectly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

**Open channels**

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United Sates Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

**Table 3-1. – Roughness coefficients (Manning's n) for sheet flow**

| Surface Description | n[1] |
|---|---|
| Smooth surfaces (concrete, asphalt, gravel, or bare soil) | 0.011 |
| Fallow (no residue) | 0.05 |
| Cultivated soils: | |
| Residue cover ≤ 20% | 0.06 |
| Residue cover > 20% | 0.17 |
| Grass | |
| Short grass prairie | 0.15 |
| Dense grasses[2] | 0.24 |
| Bermudagrass | 0.41 |
| Range (natural) | 0.13 |
| Woods:[3] | |
| Light underbrush | 0.40 |
| Dense underbrush | 0.80 |

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. this is the only part of the plant cover that will obstruct sheet flow.

# Typical Results of Pond Routing

Summary Table

| | Storm Event | | | |
|---|---|---|---|---|
| | 2 yr | 10 yr | 25 yr | 100 yr |
| Peak Flow In, Qin (cfs) | | | | |
| At Time, t (hr) | | | | |
| Total Volume (ac-ft) | | | | |
| | | | | |
| Peak Flow Out, Qout (cfs) | | | | |
| At Time, t (hr) | | | | |
| Total Volume (ac-ft) | | | | |
| | | | | |
| Max Vol Stored in Basin (cf) | | | | |
| Max Elevation in Basin (ft) | | | | |

# Typical Results of Pond Routing

Summary Table - Example

| | Storm Event | | | |
|---|---|---|---|---|
| | 2 yr | 10 yr | 25 yr | 100 yr |
| Peak Flow In, Qin (cfs) | 4.30 | 9.87 | 12.96 | 18.70 |
| At Time, t (hr) | @12.31 h | @12.15 h | @12.12 h | @12.12 h |
| Total Volume (ac-ft) | .258 AF | .734 AF | 1.001 AF | 1.50 AF |
| | | | | |
| Peak Flow Out, Qout (cfs) | 0.43 | 1.18 | 4.15 | 11.50 |
| At Time, t (hr) | @14.25 | @13.14 | @12.54 | @12.30 |
| Total Volume (ac-ft) | .258 AF | .734 AF | 1.001 AF | 1.50 AF |
| | | | | |
| Max Vol Stored in Basin (cf) | .213 AF | .418 AF | .490 AF | .558 AF |
| Max Elevation in Basin (ft) | 301.77’ | 303.11’ | 303.52’ | 303.90’ |

# Guidance for the Submittal of Culvert Design and Analysis

This guidance sheet is intended to assist in the preparation of plans and drainage analyses for culverts that carry freshwater wetland flow, in a manner that will help allow for a clear and expeditious review.

- Plans and analyses prepared with attention to the following guidance needs to accompany applications for all culverts that carry freshwater flow.
- Definition: (from Hydraulic Design of Highway Culverts, FHWA, 1985), a culvert is a hydraulically short conduit which conveys stream flow through a roadway embankment or past some other type of flow obstruction.
- In order to address *Rule* 11.02(18), culvert analyses, the changes in wetland water level in the 2, 10, 25, and 100 year, 24-hour, Type III storm events must be evaluated. The analyses need to evaluate the pre-project vs. post-project wetland water levels for these events, especially for the areas located upgradient of the culverts.
- Peak runoff discharge rates (PRODR's) for the 2, 10, 25, and 100 year 24-hour Type III storm events need to be developed for both pre-and post-project conditions. The engineer should provide adequate analysis documentation including pertinent subwatershed maps, of contributing areas, curve numbers, and time of concentration flow paths.
- For the hydraulic analyses of the culvert(s), the methodology used in Hydraulic Design of Highway Culverts Hydraulic Design Series No. 5), 1985, published by the Federal Highway Administration, should be used. Alternative methods may be used, provided that they employ analysis of the culvert(s) for both inlet and outlet control conditions, and provided that proper reference information is supplied.
- The title and version of any and all computer models that are used in the analyses should be provided.
- For any and all submittals that utilize computer model(s), appropriate documentation of all formulas and methods that the model(s) employ(s) should be provided. All input and output terminology should be clearly indicated and explained.
- If the analysis is performed by methods other than computer models, the pertinent methodology and equations that are used in the analysis should be provided.
- The analysis needs to indicate the culvert material (along with pertinent n-value), the upgradient and downgradient invert elevations, culvert length, and number of barrels.
- Adequate downgradient topography of the watercourse involved should be provided. Any and all downstream features that will have an effect on culvert tailwater elevations should be indicated.
- Any and all pertinent calculations related to the determination of culvert tailwater elevation should be provided.
- Sufficient topography of any storage area located upgradient of the culvert should be provided on the plans.
- The culvert analysis needs to include any and all storage routing analysis that was performed. Note that the performance of a storage routing analysis will allow a more accurate determination of the actual peak discharge rates than will be handled by the culvert. Storage routing should be performed by the Storage Indication Method. Pertinent reference information for any computer program used to perform the storage routing should be provided.

- As part of any storage routing analysis submitted, a table should be provided that indicates elevation vs. storage volume vs. culvert discharge.
- An adequate plan and cross-section drawings of the culvert site should be provided. The plan view needs to indicate existing and proposed topography, the extent of any and all scour protection at entrance and outlet, and the dimensions of the culvert. The cross-section view needs to indicate the culvert size, length, entrance and outlet invert elevations, number of barrels, material, the existing and proposed ground surface, and the details and specifications of any end treatments(s) and or scour protection (flared end sections, headwalls, riprap, etc.). The cross-section must be to scale. The roadway / driveway elevation(s), both existing and proposed should be provided.
- Provide a profile view, drawn to scale, along the roadway/driveway, showing the existing and proposed grade. Indicate the culvert opening on this profile.
- The elevations of the peak wetland water levels, including any overtopping flows, for the 2,10, 25, and 100 year 24 hour Type III storm events, for both the existing and proposed conditions should be indicate on either the cross-section view or the profile view, or both.
- The plans should include an inspection and maintenance program for the proposed culverts. This needs to include:
- The name of the party to be responsible to ensure that the inspection and maintenance is carried out.
- The frequency of the routine inspection.
- The removal of accumulated sediment and debris, which may tend to adversely affect the culvert's hydraulic performance.
- Note: The use of Manning's equation methods as the sole method to size and/or analyze a culvert is not considered acceptable. Although use of Manning's equation methodology provides the full flow of a pipe at a given slope, the inherent assumption is that the flow has already entered the pipe. The analysis of a culvert needs to address the matter of determining the head that is needed to allow a given quantity of flow to enter a pipe/culvert. Therefore, the analysis for inlet control conditions is necessary.
- Note: If the analysis of the proposed culvert indicates that there will be an increase in wetland water levels upgradient of the proposed culvert in the 2, 10, 25, and/or 100 year 24 hour Type III storm, and if such increase in peak wetland water level occurs on property that is not owned by the applicant, then one of the following must be obtained:
  - ➢ Provide a drainage easement(s) from the owner(s) of the affected property(ies).
  - ➢ Make that/those owner(s) a co-applicant(s).
  - ➢ Provide a letter of authorization from the affected property owner(s) to allow the specified increase in peak wetland water level.
- Note: Typically, the DEM/Freshwater Wetlands Program does not require specific design analysis and impact evaluation for culverts that do not carry flow into, out of, or between freshwater wetland areas. These culverts (such as driveway culverts) do not necessitate a submittal of analysis to this office, unless they involve flow carried by ASSF's (areas subject to storm flow).
- Note: Under RIDEM/ Freshwater Wetlands Program Rule 6.03, certain limited maintenance and repair activities of culverts may be exempt as per the following provisions:

  6.03 Limited Maintenance and Repair Activities

  The following limited repairs to, and maintenance of approved or existing structures in current use located in wetlands are allowed in accordance with Rule 6.01 and provided that the maintenance activity does not increase either vertically or horizontally the physical size of any existing structure. However, some limited structural changes may be exempt as specifically provided below.

  B. Replacement of functional drainage structures, provided that:

  1.) Culverts of more than fifty feet (50') are the same type, size, length, capacity,

and invert elevation as the present structure;
2) Culverts of fifty feet (50’) or less maintain the same slope, a nominally equivalent cross-sectional area and the same invert elevation as the present with no more than five foot (5’) extensions in length on either end;
3)The project does not result in sediment transport to wetlands or any filling, draining or impoundment of wetlands beyond what was approved or existing; and
4) The property owner maintains site plans which detail the condition of the drainage structure as it existed prior to replacement. A riprap scour pad not greater than ten feet (10’) in length may be placed at the culvert outfall if an erosion problem is evident, provided that access for fish and wildlife is not impeded.

D. Cleaning of drainage pipes, culverts, catch basin and manholes.